Observing Gravity Waves Via Satellite: Measuring Horizontal Wavelength and Wave Momentum Flux

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- Reference:
  Preusse, et al., 2003: Estimates of the Horizontal Wavelengths of Gravity Waves and the Implications for the Tropical Maximum Observed in Satellite Climatologies, (submitted to JGR).

  http://www.fz-juelich.de/icg/icg-i/www_export/user/p.preusse/jgr_horwavl/vl_nt.pdf

Gravity Waves in Limb Sounding Satellite Data

- Atmospheric gravity waves are ubiquitous features in measurements, but have scales generally too small to resolve in global assimilations.
- They have wide-ranging effects including:
  - *(i)* wave momentum drag forcing of the general circulation,
  - *(ii)* modulation of ice cloud formation in the upper troposphere and lower stratosphere region, and
  - *(iii)* related effects on ozone chemistry at high latitudes and water vapor concentrations near the tropical tropopause.
- Gravity waves are usually observed via satellite as temperature perturbations in vertical profiles.
- Such observations can then give wave temperature amplitudes T' and vertical wavelengths λ_Z.

Gravity Wave Theory

- Gravity wave theory gives the relationship between temperature amplitude T' and pseudomomentum flux M for low-frequency waves likely visible in the HIRDLS measurements:
$$M = \frac{\bar{\rho} g^2 \omega}{N^3} \left(1 - \frac{f^2}{\omega^2}\right)^{1/2} |\hat{T}|^2$$
where $\hat{T} = T'/\overline{T}$
- ω is the intrinsic frequency that varies with height through variable background wind
$$\omega = \omega_0 - \bar{u}(z)k$$
.
- ω can be related via the dispersion relationship to the horizontal and vertical wavenumber (k, m) information in the measurements. For the waves observable by HIRDLS this is approximately
$$\omega^2 = \frac{N^2 k^2}{m^2} + f^2$$
- Substituting gives
$$M = \frac{\bar{\rho} g^2}{N^2} \frac{k}{m} |\hat{T}|^2$$

Voila?

Horizontal Wavelength from Satellite Limb Profiles

- Consider a wave propagating in the x-z plane with temperature perturbations:

$$T(x, z, t) = T'(z) sin(kx + mz - \omega t + \psi)$$

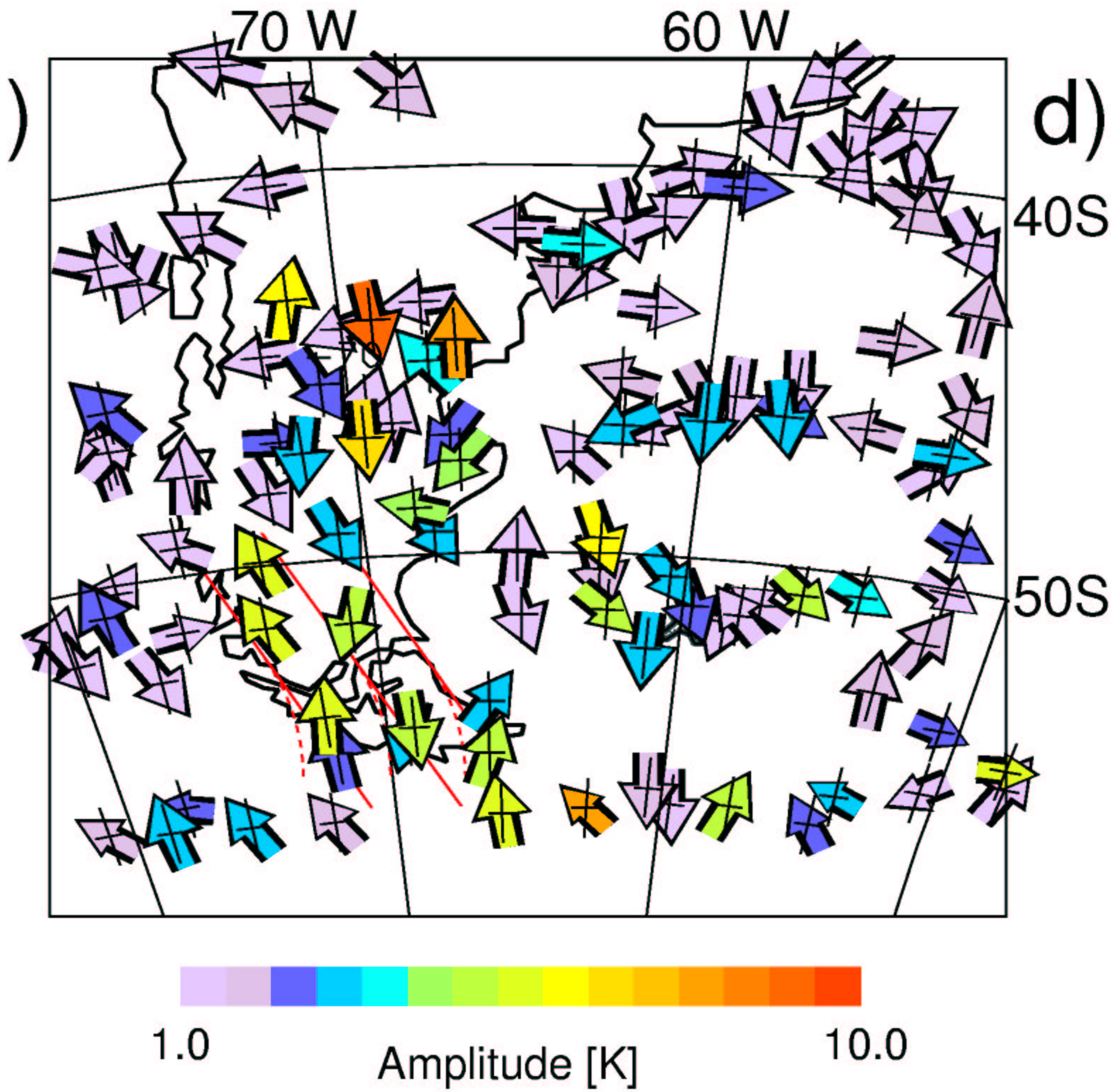
- Analysis of limb profiles gives wave amplitude $T'(z)$, vertical wavenumber m, and phase $\phi(x, z) = kx + mz + \psi$. We can neglect the time dependence because the wave period is much longer than the time difference between adjacent profile measurements.

- The change in phase between adjacent profiles at a given height gives the horizontal wavenumber k:

$$k = \frac{\partial \phi(x, z)}{\partial x} = \frac{\Delta \phi}{\Delta x}$$

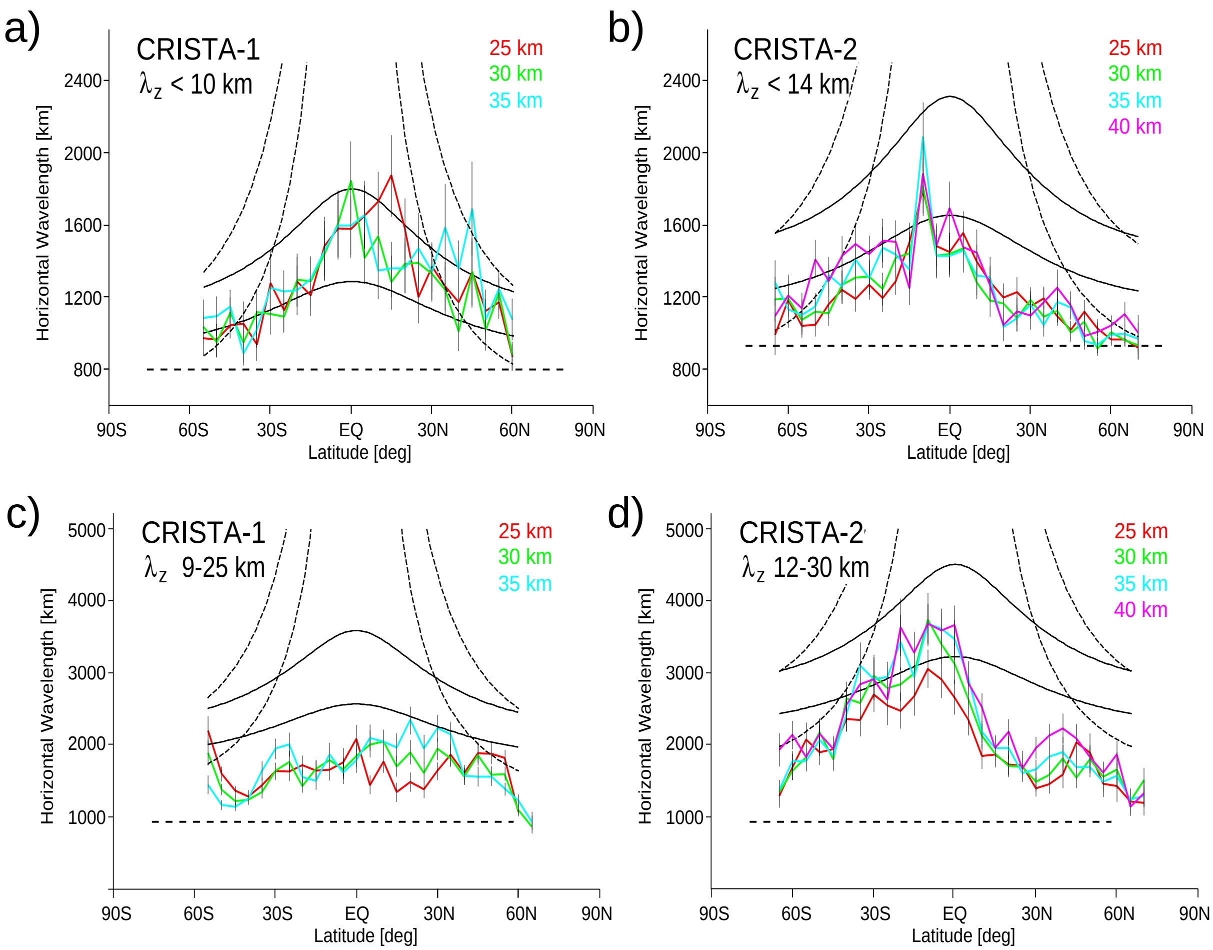
- Only two adjacent profiles are required to deduce a horizontal wavelength.

- Note that if we had three adjacent profiles forming a right angle, they could be used to deduce both horizontal wavelength and direction of horizontal propagation.



)
70 W
60 W
d)
40S
50S
1.0
10.0
Amplitude [K]

Horizontal Wavelength vs Latitude
Derived from Along-Track Differences



	CRISTA-1	CRISTA-2
Nyquist wavelength	400km	480km
Minimum wavelength	800km	960km
Maximum wavelength	4800km	5760km